REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
		Final Report 1/1/95-5/31/96

4. TITLE AND SUBTITLE
Equipment for Visualization of Large-Scale Fluid Dynamics Calculations

5. FUNDING NUMBERS
F 49620-95-1-0100

6. AUTHOR(S)
Paul Fischer C-W Shu
W.S. Don
D. Gottlieb

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Division of Applied Mathematics
Brown University
Providence, RI 02912

ORGANIZATION

AFOSR-TR-96
0542

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Office of Scientific Research
110 Duncan Avenue, Suite B 115
Bolling AFB, DC 20332-8080

nm

10. SPONSORING... ORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

see attached

14. SUBJECT TERMS			15. NUMBER OF PAGES
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT

Final Technical Report for AFOSR Grant # F49620-95-1-0100

Equipment for Visualization of Large-scale Fluid Dynamics Calculations

Paul Fischer
Division of Applied Mathematics
Brown University
Providence, RI 02912

Technical Objectives

Grant # F49620-95-1-0100 was a DURIP equipment Grant in support of ongoing research in high-order numerical methods at Brown University. The equipment purchased included a 1 Gbyte SGI Onyx, and two smaller SGI Indigo II's for Professors Gottlieb and Don, as well as ATM switching network for improved data transfer within the Center for Fluid Mechanics computing center which supports our scientific computing group. The SGI Onyx is being used by many faculty and students in the scientific computing group and Center for Fluid Mechanics in applied mathematics.

The principal aims of providing the Onyx as large memory compute server were to provide graphics capability for the analysis of large two- and three-dimensional data sets arising in computational fluid dynamics simulations carried out at remote supercomputing sites, and to provide a local *serial* platform with sufficient RAM to permit rapid development of iterative solvers which are to ultimately be implemented on remote parallel supercomputers. The ATM network and smaller SGI's facilitates data transfer between the Onyx graphics/compute server and individual workstations as well as improved data throughput to and from the diskfarms.

Equipment Purchased

Please see attached.

Technical Accomplishments

Flow Visualization

We primarily use flow visualization as a tool rather than undertake development of visualization software. One of the SGI Indigo II's is used by Prof. W.S. Don to study shock induced vortex formation in hydrogen-air mixtures for scramjet combustors. The Indigo II has greatly reduced rendering times for computational results of his 512×512 spectral calculations, allowing him to view more frames of data and consequently pinpoint some of the critical phenomena in flame front enhancement. Visualization of this type is a powerful

tool to aid both numerical and experimental researchers in this project in developing a better understanding of combustion dynamics.

Visualization on the SGI Onyx is currently being used to analyze heat transfer in three-dimensional models of high-performance heat exchangers by Prof. Fischer, and in the study of turbulence by researchers in the Center for Fluid Mechanics group with whom we share systems and network support. Prof. Don has recently undertaken three-dimensional simulations which will necessitate the use of the Onyx as a graphics engine due to memory requirements.

Iterative Algorithm Development

The acquisition of the SGI Onyx has been instrumental in the recent development of an overlapping Schwarz iterative scheme for spectral element solution of the Navier-Stokes equations and Grant # F49620-95-1-0100 has been cited for computational support of this project in [1]. This new iterative algorithm yields a five-fold reduction in CPU time for current production runs and is inherently parallel. The resultant code is currently being used by NASA contractors in the study of Helmholtz resonators used for aircraft noise suppession.

Because of the large memory capacity of the Onyx, we were able to test and develop serial versions the algorithm in house on fluid dynamics simulations of production size (up to 500,000 gridpoints). Consequently, we could study the performance of the algorithm under severe test conditions without the unnecessary burden of implementing a fully functional parallel version or of having to repeatedly ship source code to a remote supercomputing site. Without the Onyx, we would have had to base the development work on the results of much smaller test computations which frequently do not reveal the weaknesses of iterative methods, or undertake the development and simultaneous debugging of parallel code which would have greatly slowed the process. It is unlikely that the new algorithm would have reached its current state of refinement if we had attempted the development remotely on a parallel computer as the turn around time at such sites is simply too slow for efficient development work.

We are presently extending the scheme to three-dimensional computations and to parallel. The three-dimensional work is being carried out on the SGI Onyx, while the parallel development is being done on the Intel Paragon at WPAFB and the Intel Delta at Caltech.

Publications

This is a one-year equipment grant which primarily addresses infrastructure improvements for scientific computing in the Applied Mathematics Division at Brown and as such does not support individual researchers. However, it was instrumental in facilitating the work detailed in the publication below and is cited as such.

[1] P. Fischer, "An overlapping Schwarz method for spectral element solution of the incompressible Navier-Stokes equations," submitted to the *J. of Comp. Phys.* (1996)

VENDOR NAME	DESC. OF EQUIPMENT	COST TO GRANT
FORE SYSTEMS	ATM INTERFACES	$4,900.35
SILICON GRAPHICS	POWER ONYX	$261,755.00
ANDATACO	8 X 4.2 GBYTE SUBSYSTEM	$17,583.42
SILICON GRAPHICS	75' CABLE & KEYBOARD FOR ONYX	$82.90
ANDATACO	128 MBYTE SIMMS	$9026.39
CISCO SYSTEMS	LIGHTSTREAM 1010 ATM SWITCH	$21,431.94
	TOTAL	$314,800.00